TECHNOLOGY NEEDS/OPPORTUNITIES STATEMENT

PROVIDE ADVANCED CHARACTERIZATION TOOLS AND METHODS TO DELINEATE CONTAMINANT PLUMES IN THE VADOSE ZONE AND RELATE PLUME DISTRIBUTION TO THE DISTRIBUTION OF GEOCHEMICAL AND HYDROGEOLOGICAL PROPERTIES

Identification No.: RL-SS31
Date: September 2001

Program: Environmental Restoration
OPS Office/Site: Richland Operations Office/Hanford Site
Operable Unit(s): Broad need potentially applicable to multiple operable units.
PBS No.: RL-SS04 (RL-VZ01)
Waste Stream: Disposition Map Designations: ER-04 [technical risk score 3], ER-14 [technical risk score 5], ER-03 [technical risk score 3]
TSD Title: N/A
Waste Management Unit (if applicable): N/A
Facility: N/A

***Priority Rating*:**

This entry addresses the "Accelerated Cleanup: Paths to Closure (ACPC)" priority:

X 1. Critical to the success of the ACPC
____ 2. Provides substantial benefit to ACPC projects (e.g., moderate to high lifecycle cost savings or risk reduction, increased likelihood of compliance, increased assurance to avoid schedule delays)
____ 3. Provides opportunities for significant, but lower cost savings or risk reduction, and may reduce uncertainty in ACPC project success.

***Need Title*:** Provide Advanced Characterization Tools and Methods to Delineate Contaminant Plumes in the Vadose Zone and Relate Plume Distribution to the Distribution of Geochemical and Hydrogeological Properties

Need/Opportunity Category: Technology Need.

***Need Description*:** This need addresses specific technical gaps identified in the scope of the Groundwater/Vadose Zone Integration Project (Integration Project) at the Hanford Site and is written as an "integrated" need. The Integration Project is focused on providing the scientific and technical basis to ensure that Hanford Site decisions, including decisions related to long-term stewardship, are defensible and possess an integrated perspective for the protection of water resources, the Columbia River, river-dependent life, and users of the Columbia River resources. As such, this "integrated" need has both applied S&T components that are interrelated in addressing the specified technical gap. Individual efforts applied to resolve the technical gaps

described in this need may address all or part of the components identified for this need. Where a specific technology need can be defined separately from an "integrated" need, a specific technology need statement has been written and is included elsewhere in the Hanford Site STCG Subsurface Contamination Needs (e.g., RL-SS25: Improved, Cost-Effective Methods for Subsurface Access to Support Characterization and Remediation).

To support both site-specific and site-wide assessments that lead to effective remediation, advanced characterization tools and methods are needed to determine nature and extent of contamination and to support field investigations to elucidate key features and processes that control contaminant migration. At present, we do not know where more than a few percent of the contaminants are located in the vadose zone (GAO 1989, Ward et al. 1997). Spectral gamma logging of tank farm subsurface contamination has not provided information about the risk drivers (^{99}Tc, ^{129}I, etc.) that currently reside in the vadose zone and are leaking into the groundwater (GJPO 1996, 1998; Conaway et al. 1997, 1998). Advanced characterization tools will provide that information, which is key to knowing when groundwater might be impacted by contaminants that are moving to the water table at accelerated rates (Johnson and Chou 1998, Hodges 1998 and Narbutovskih 1998) from Hanford waste sites (tanks, cribs, trenches, etc.). This information is presently lacking in all the waste management areas (100, 200, 300) but is particularly critical to waste disposal decision in the 100 and 200 Areas, where some wastes may be left in place and isolated with engineered barriers. The potential for migration and the monitoring verification of the contaminant mobility will depend on characterization tools that currently are not deployed at the Hanford Site.

The primary technical gap associated with delineating contaminant plumes in the vadose zone is insufficient soil, geophysical, geochemical, and hydrological data or methods to resolve subsurface heterogeneities, characterize geohydrologic properties, and map contaminant distributions at different scales in the vadose zone. This information is important to determine the physical and chemical properties/parameters of the vadose zone as well as the water and contaminant distribution and flux for use in assessing the potential for future migration or remobilization of contaminants. Specific issues that need to be addressed to resolve this technical gap include the following.

- Characterization methods are needed to define the in situ physical and chemical aspects of the vadose zone, and average field-scale properties describing fluid flow and reaction. These methods need to have the sensitivity to characterize subsurface geohydrologic and geochemical properties with sufficient accuracy to permit prediction of contaminant fate and transport. Specific information needed includes the following: Techniques are needed to determine the distribution of subsurface heterogeneities (natural and those created by waste interaction with the porous medium) that may influence the distribution of soil water and contaminants. Additionally, techniques are needed to delineate the three dimensional (3D) distribution of geohydrological properties in the vadose zone. Techniques are also needed to extrapolate the classical measurements of geohydrologic and transport properties made on small, homogeneous soil cores and in small near-surface experiments to the pertinent field scale at which soil parameters exhibit complex natural heterogeneity.

- Characterization methods are needed to delineate the 3D size and shape of contaminant plumes in the vadose zone. Specific information needed includes the following: Information is needed about how contamination is distributed in the vadose zone beneath different types of waste sites with different source chemistries and different release histories. Information is needed to understand the existing physical, chemical, and mineralogical associations of contaminants and co-contaminants and determine the primary processes that have formed these associations. Information is needed to understand the relationships between contaminant distribution, moisture content, and the physical, chemical, microbiologic, and geologic characteristics of the subsurface sediments. In addition, techniques are needed to map groundwater contaminants and other dissolved species that have reached the groundwater back to their sources.

- Information is needed to determine the chemical form and mobility of dense, non-aqueous phase liquids (DNAPLs and related contaminants, such as chlorinated solvents in contact with (1) pore water and (2) secondary minerals. The distribution of DNAPLs in the vadose zone can greatly affect the cleanup efficiencies and thus affect costs of cleanup (e.g., over 80% of the carbon tetrachloride inventory is assumed to lie above the water table but its distribution within the vadose zone is unknown). Determination of form and distribution of DNAPLs in the vadose zone will help prioritize cleanup strategies and may greatly reduce cleanup time and costs (Science Need RL-SS25-S).

- Information is needed to understand the physics and chemistry principles that underlie more accurate, more sensitive, and higher resolution measurements of contaminant concentrations in the aqueous and solid (surface) phases. Recent theoretical developments on electromagnetic and electrical field analysis in zones containing high metal contents (buried pipes, well casings, etc.)could lead to less expensive methods for minimally intrusive measures of subsurface contaminant plumes (Science Need RL-SS37-S).

- The Hanford site contains large volumes of contaminated vadose zone and aquifer soils. In some areas, these soils are located at depths of 500 ft while access to other soils is restricted by the presence of surface or near surface objects such as buildings or underground tanks. The Hanford geology also is quite varied and ranges from unconsolidated silty sands to gravels and cobbles. Cost effective technologies that allow access to this wide variety of sediments for both characterization and remediation are required (Technology Need RL-SS25).

- Contaminants with low distribution coefficients and long half-lives like ^{99}Tc and ^{129}I tend to represent the greatest health risks in long-term risk assessments for the 200 Area tank farms. Also, strontium contamination in the 100 Area soils and ground water presents a near term environmental concern due to its close proximity to the Columbia River. However, it is difficult to measure the inventories and distribution of these contaminants because they only emit beta

particles that do not penetrate the surrounding soil. Therefore, the only way to currently obtain data in the vadose zone is through the costly collection of soil samples. Improved, more cost-effective methods of accessing contaminated soils, taking soil samples, and/or measuring the concentration of beta emitting contaminants are required (Technology Need RL-SS26).

Other technology needs that relate to this need include RL-WT102 and RL-WT026.

Schedule Requirements:

Earliest Date Required: 8/1/99

Latest Date Required: 9/30/05

The Integration Project S&T roadmap (DOE/RL-98-48, 2000) indicates the information that is required over the next 6 years to meet the objectives of the Integration Project. Information associated with delineating contaminant plumes in the vadose zone is needed in the FY02 to FY03 timeframe to meet these objectives.

***Problem Description*:** This need falls under the Vadose Zone Technical Element within the S&T Endeavor. The Vadose Zone Technical Element is intended to address and resolve scientific problems related to the leakage of radioactive and hazardous wastes into Hanford soils and sediments. The objective of the Vadose Zone Technical Element is to enhance protection of human health and the environment by providing 1) improved models, measurements, and data to predict contaminant migration and provide warning of potential surface or groundwater contamination before problems arise; 2) scientific rigor to system assessment and PA models as they are developed, reviewed, and implemented; and 3) scientific support for selection of the most safe, efficient, and effective remedial actions and site closure activities. An implicit goal of this research is to provide scientific and regulatory credibility to DOE's environmental management decision-making process.

The scope of this technical element encompasses the unsaturated zone beneath the Hanford Site. The geographic focus is on areas that (1) underlie liquid waste disposal sites; (2) have the potential for leaks or leaching; and (3) have experienced past leaks and spills. Also included are selected areas away from the focus areas, such as areas representative of background conditions, and areas that have the potential to become contaminated in the future.

Specific topics for this need include (1) improved downhole otherwise minimally intrusive methods for determination of physical and chemical properties/parameters of the Hanford vadose zone and (2) improved downhole and minimally intrusive methods for determination of contaminant distribution and flux.

Benefit to the Project Baseline of Filling Need: The application of surface barriers and other remediation strategies currently planned for the Hanford Site depends on improved measurements of transport processes in the vadose zone. Confidence in predicting contaminant travel times at treated or covered sites will be enhanced by implementing this advanced characterization activity. Successful

completion of these activities is required to meet the objectives of the Integration Project and the related elements of the Paths to Closure.

***Functional Performance Requirements*:** The techniques applied or information that is obtained must delineate contaminant plume distributions and geochemical and hydrogeological property distributions such that the information can be applied toward the conceptual models, fate and transport numerical models, and system assessment capabilities that are being developed as part of the Integration Project.

Work Breakdown Structure (WBS) No.* :** 1.4.03.4.4 ***TIP No.: TIP-0013

Relevant PBS Milestone: PBS-MC-042

***Justification For Need*:**

Technical: There are insufficient soil, geophysical, geochemical, and hydrological data or methods to resolve subsurface heterogeneities, characterize geohydrologic properties, and map contaminant distributions at different scales in the vadose zone. This information is important to determine the physical and chemical properties/parameters of the vadose zone as well as the water and contaminant distribution and flux for use in assessing the potential for future migration or remobilization of contaminants.

Regulatory: Information obtained by addressing this need will provide an improved technical basis for making site regulatory decisions and therefore reduce the uncertainty associated with the basis for these decisions.

Environmental Safety & Health: This need addresses broad sitewide technical issues and, as such, crosscuts multiple applications that each may have specific environmental safety and health issues.

Potential Life-Cycle Cost Savings of Need (in $000s) and Cost Savings Explanation: The estimated life-cycle cost savings associated with filling this need is $200M. This estimate is based on an assumed savings of 5% of the total Hanford remediation life-cycle cost of >$5B. Estimated savings are due to information and data gained by filling this need that supports decisions for cost effective remediation and long-term stewardship.

Cultural/Stakeholder Concerns: This technology need supports the resolution of cultural and stakeholder concerns as expressed by the CRCIA Team in “Columbia River Comprehensive Impact Assessment, Part II: Requirements for a Columbia River Comprehensive Impact Assessment” (DOE 1998).

Other: None.

Current Baseline Technology: N/A

End-User: Richland Environmental Restoration Project

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DOE End-User/Representative Point-of-Contact: John G. Morse, DOE-RL, (509) 376-0057

References:

Conaway, J.G., Luxmoore, R.J., Matuszek, J.M., Patt, R.O., Wierenga, P.J., Shafter, D.S., 1998. Vadose Zone Expert Panel Meeting, Meeting Closeout Report. DOE/RL-98-67. U.S. Department of Energy, Richland, WA, 99352.

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GJPO 1996. SX Tank Farm Report. DOE/ID/12584-268. U.S. Department of Energy, Grand Junction Projects Office, Grand, Junction, Colorado.

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Hodges, F.N., 1998. Results of Phase I Groundwater Quality Assessment for Single-Shell Tank Waste Management Areas T and TX-TY at the Hanford Site. PNNL-11809. Pacific Northwest National Laboratory, Richland, WA, 99352

Johnson, V.G., Chou, C.J., 1998. Results of Phase I Groundwater Quality Assessment for Single-Shell Tank Waste Management Areas S-SX at the Hanford Site. PNNL-11810. Pacific Northwest National Laboratory, Richland, WA, 99352

Narbutovskih, S.M., 1998. Results of Phase I Groundwater Quality Assessment for Single-Shell Tank Waste Management Areas B-BX-BY at the Hanford Site. PNNL-11826. Pacific Northwest National Laboratory, Richland, WA 99352

United States Department of Energy. 1998. Columbia River Comprehensive Impact Assessment, Part II; Requirements for a Columbia River Comprehensive Impact Assessment. DOE/RL-96-16. United States Department of Energy, Richland, Washington.

United States Department of Energy. 2000. Groundwater/Vadose Zone Integration Project Science and Technology Summary Description. DOE/RL-98-48, Vol. III, Rev. 1, U.S. Department of Energy, Richland, Washington.

Ward, A. L., G. W. Gee and M. D. White. 1997. A comprehensive analysis of contaminant transport in the vadose zone beneath tank SX-109. PNNL-11463. Pacific Northwest National Laboratory, Richland, Washington.

Groundwater Element Index to Linked Needs.

RL-SS32	Understand and Quantify the Relationship Between Contaminant Sources, Vadose Zone Plume Properties and Groundwater Plume Properties with a Focus on the Groundwater-Vadose Zone Interface
RL-SS03	Improved, Real-Time, In-Situ Detection of Carbon Tetrachloride in Groundwater
RL-SS06	Improved, Real-Time, In-Situ Detection of Hexavalent Chromium in Groundwater
RL-SS33	Provide Means to Delineate Regional Groundwater Plumes in Three Dimensions and Define a Science Basis for Addressing Scaling Issues in Hanford Groundwater
RL-SS25	Improved, Cost-Effective Methods for Sub-Surface Access to Support Characterization and Remediation
RL-SS34	Understand, Quantify and Develop Descriptions of Biogeochemical Reactions and Interactions Between Contaminants of Concern and Aquifer Sediments to Describe Biochemical Reactive Transport
RL-SS23-S	Chemical Speciation and Complexation in Site-Specific Groundwaters
RL-SS24-S	Chemical Binding on Site-Specific Mineral Surfaces
RL-SS25-S	Chemical Form and Mobility of Dense, Non-Aqueous Phase Liquids in Hanford Subsurface Transport of Contaminants
RL-SS26-S	Reaction Rates for Key Contaminant Species and Complexes in Site-Specific Groundwaters
RL-SS27-S	Rate of Coupled Abiotic and Biogeochemical Reactions Involving Contaminants in Hanford Subsurface
RL-SS28-S	Rates of Colloid Formation and Colloidal Transport of Contaminants in Site-Specific Groundwaters
RL-SS31-S	Mathematical Formulations of Chemical Reaction/Material Transport
RL-SS32-S	Reactivity of Organics in the Hanford Subsurface
RL-SS35-S	Use of Chemical surrogates for Contaminants
RL-SS35	Provide Means to Quantify the Flux of Contaminant Between the Groundwater and the Columbia River